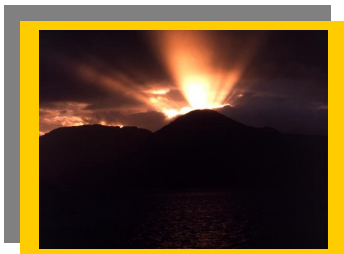


## The Sun and Solar Wind: A Search for the Beginning

## Here Comes the Light!

### TEACHER GUIDE

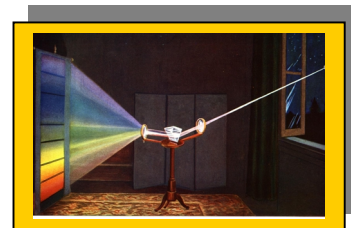
### BACKGROUND INFORMATION



This activity introduces students to the use of a spectroscope and to the nature of radiant energy, with special emphasis on visible light. At the end of the activity they will investigate the famous Fraunhofer spectral lines and prove that the sun is composed of other elements in addition to hydrogen and helium, which of course are the two key elements of the Standard Solar Model.

The first part of the activity familiarizes students with the use of a spectroscope, where they initially will observe two fundamentally different kinds of spectra from common sources—such as incandescent and fluorescent lamps. They will learn that there are both quantitative and qualitative observations that can be made and they will be introduced to the idea of calibration of instruments.

Following the introductory investigations, the students will observe the spectrum of a number of additional incandescent solid objects (at the discretion of the teacher). They will then gain experience in the use of the spectroscope to investigate the emission lines of a series of thermally excited elements and other easily available light sources. These lines of investigation will lead them to discover some aspects of the first two of Kirchhoff's laws, which state that:



- a. A liquid, solid, or gas at high pressure will produce a continuum spectrum when heated to incandescence. That is to say, the visible spectrum from the source will contain all wavelengths of light.
- b. A gas, when heated under low pressure, will emit only bright spectral lines at certain characteristic wavelengths rather than a continuum.

The students will then be introduced to the idea of an absorption spectrum and they will make observations on both ionic materials and molecular materials. The critical difference between emission and absorption spectra will be emphasized. This then will be related to Kirchhoff's third law, which states that:

- c. If a cool gas is placed in front of a hot, incandescent, continuous-spectrum source it will absorb certain colors or wavelengths from the continuum spectrum of the source.

The third law will not be investigated directly in this activity because such experiments are difficult to set up. Nevertheless, based on their understanding of absorption the students should be able to rationalize the third law.

Finally, the students will turn their attention to the sun and use their knowledge to identify a heavy element in the sun's outer layer.

This activity is very flexible in nature and the exact procedures followed will depend on the materials and spectroscope(s) that you have available. The students are encouraged to pursue independent lines of investigation as well. However, it cannot be overemphasized that **UNDER NO CIRCUMSTANCES SHOULD THE STUDENTS TRY TO OBSERVE THE SUN DIRECTLY.**

## STANDARDS ADDRESSED

### Grades 5-8

#### [Science as Inquiry](#)

Abilities necessary to do scientific inquiry  
 Understandings about scientific inquiry

#### [Science and Technology](#)

Understandings about scientific and technology

#### [Physical Science](#)

Structure and changes in properties of matter  
 Transfer of energy

#### [History and Nature of Science](#)

Science as a human endeavor  
 Nature of science and scientific knowledge  
 History of science and historical perspectives

### Grades 9-12

#### [Science as Inquiry](#)

Abilities necessary to do scientific inquiry  
 Understandings about scientific inquiry

#### [Science and Technology](#)

Understandings about scientific and technology

#### [Earth and Space Science](#)

The origin and evolution of the Earth system  
 The origin and evolution of the Universe

#### [Physical Science](#)

Structure and changes in properties of matter  
 Transfer of energy  
 Structure of atoms

#### [History and Nature of Science](#)

Science as a human endeavor  
 Nature of science and scientific knowledge  
 History of science and historical perspectives

[For full text of National Standards addressed in this module, see [Appendix D](#).]

## MATERIALS

For each student:

- Copy of Student Activity "[Here Comes the Light!](#)"
- Copy of Student Text "[Electromagnetic Radiation](#)"
- Copy of Student Text "[The Fraunhofer Lines](#)"
- Copy of Student Reporting/Data Sheet "[Here Comes the Light!](#)"
- Copy of solar spectrum with selected Fraunhofer lines marked (see procedure steps #1 and #10)

For each student or group of students

- A set of colored pencils or markers that include the basic colors red, orange, yellow, green, blue and violet.
- Small hand-held spectroscope—preferably more than one, depending on class size. (Inexpensive models may be purchased from scientific supply houses such as Edmund Scientific at a nominal cost. Alternately more advanced students can build quite a good spectroscope by following directions given by Thompson. The better the quality of spectroscope, the more quantitative this activity can be made. [See [TEACHER RESOURCES](#) for more information on Edmund Scientific and Thompson article.]

### Caution!

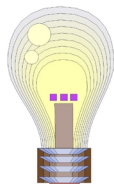
Caution the students never to look directly at the sun with the spectroscope. To do so could result in serious damage to their eyes.

In addition, for Part 2:

A 60 watt or smaller frosted or clear light bulb, with a fixture

Optional incandescent samples for Part 2:

Incandescent objects such as hot glowing metal strips, glowing hot chunks of charcoal, or hot pieces of glass. (These are optional, but strongly recommended to make it easier for students to formulate ideas resembling Kirchoff's first law.)

In addition, for Part 3:

Fluorescent lamp and fixture

In addition, for Part 4:

Objects with a shiny metal surface, such as the bottom of a stainless steel frying pan

**Teaching Tips**

You may wish to have **beginning students stop after completing Part 4** of this activity. At this point, they should be able to conclude that the sun is a hot, glowing incandescent object that gives a continuum spectrum rather than a line spectrum and be able to understand and, perhaps, apply the first two of Kirchoff's laws.

In addition, for Part 5:

Powdered samples of sodium and strontium salts, such as NaCl and  $\text{SrCl}_2$

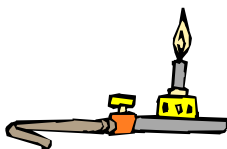
A Bunsen burner

Optional samples for Part 5:

Spectral Tubes

Cyalume Light Stick®

LED's

**Teaching Tips**

It is essential that students view the light from at least one source, the most convenient and satisfactory being a standard, frosted light bulb. A clear bulb can be used as well and is preferable if students are not aware of the existence of the glowing, hot, metallic filament inside the bulb as the source of the electromagnetic radiation.

The wattage is arbitrary, but it should be no more than 60 watts. Smaller wattages are preferable and quite satisfactory. If a 60-watt bulb is used, make sure students aim the spectroscope's slit away from the brightest portion of the light bulb.

**Safety Tips**

Set up equipment used in Part 2 in stations around the lab, making sure that appropriate safety precautions are observed. For example, set up the light bulb toward the back of the lab desk so that it is less likely that students will touch it accidentally.

The glowing samples—charcoal, gas, and metal—should be set up under an exhaust hood or in another secure location so that students do not need to move or touch the torches or burners.

Post safety signs, such as "Do NOT touch the hot bulb," "Do NOT look directly at the sun," and "Do NOT touch glowing samples," at appropriate stations.

**Teaching Tips**

Make available as many samples for students to observe as possible. Although the primary interest of this activity is the spectra of atomic materials and simple ions, molecules often emit light in the visible part of the spectrum as well. The phenomenon is the same. Electrons that have been excited to higher energy states by external stimuli such as chemical energy or electrical energy fall back to lower states with the emission of photons.

Suggested samples for observations of atomic species are: (1) sodium and strontium lines; and (2) lines from commercial light spectrum tubes. The bright sodium and strontium spectra can be observed in the flame of a Bunsen burner when a small amount of powdered salts (e.g. NaCl or  $\text{SrCl}_2$ ) is introduced into the air ports.

Spectrum tubes can be purchased from science supply houses.

Cyalume light sticks, which emit in the green, are available in stores selling party supplies or, sometimes, from local army reserve stations. A good side project would be for the students to determine what is in a light stick.

The students may also observe emission from LED's near 670 nm (if they are large enough to put out enough light for observation), and from the phosphors of computer screens. (It is best to mask off most of the screen, leaving a colored band across it for observation.)

In addition, for Part 6

Vanish® toilet bowl cleaner dissolved in water; it contains blue copper phthalocyanine, which absorbs in a broad band from about 525 to 665 nm.

Solutions of food coloring having various colors

Theatrical lighting filters, also called theatre gel

At least one of the following if at all possible: glassblower's protective glasses; salts of the rare earth elements neodymium and/or holmium

Optional samples for Part 6:

Colored glass, such as the "cobalt" glass used in traditional qualitative analysis flame tests conducted in chemistry classes and/or samples of decorative glass having various colors.

In addition, for Part 6:

A solar spectrum chart like No. J36, 424 from Edmund Scientific. [See [TEACHER RESOURCES](#).]

**Teaching Tips**

Once again make available as many samples of materials for observation as is practical. Have students place the material between a light bulb and the spectroscope. Upon viewing the light in the spectroscope they will see that the material has removed one or more wavelengths or even a broad portion of the continuum spectrum. Atomic materials that are carefully selected give rise to absorption lines whereas molecular materials give rise to broad regions of absorption, called bands.

Have the students investigate at least one of the following, if possible:

- (1) the glass in the protective glasses worn by glassblowers, which contains the rare earth neodymium and absorbs light at 430, 350, 530, 580, and 690 nm as reasonably broad bands having half-widths of about 10 nm;
- (2) a neodymium salt dissolved in water; or
- (3) a holmium salt dissolved in water, which provides rather narrow but strong absorption lines at 415, 450, 535, and 640 nm. If aqueous solutions are used place them in clear glass containers that can be held between the light source and the spectroscope.

**PROCEDURE**

## 1. Before class make copies of:

Student Activity "Here Comes the Light!"

Student Text "Electromagnetic Radiation"

Student Text "The Fraunhofer Lines"

For students who will be completing all parts of the exercise make copies of:

Handout "Table of Strong Fraunhofer Lines"

Handout "Solar Spectrum" with selected Fraunhofer lines marked as necessary, from the Web sites specified (see below).

Collect materials as listed above for those parts of the exercise you plan to assign.

## 2. Distribute copies of Student Activity and Handout sheets.

**Teaching Tips**

Some spectroscopes may give readings in nanometers, but others may be in Angstrom units (1 Ångstrom is  $1 \times 10^{-10}$  m). Make sure that the students know what units are being used. Have them work out a conversion factor between Angstrom units and nanometers ( $1 \text{ nm} = 10 \text{ Å}$ ).

3. Ask questions similar to the following to determine students' understanding of spectroscopy use:
  - a) What is the purpose of a spectroscopy? Make sure that the students understand that the spectroscopy measures the wavelength of light and that the scale seen in the spectroscopy may be given in one of several units, depending on the manufacturer.
  - b) Why is the scale they see in the spectroscopy not necessarily accurate?
  - c) What does it mean to calibrate an instrument, like a spectroscopy?
  - d) How is the process of calibration carried out?
4. Introduce the following terms:
  - a) continuum spectrum,
  - b) line spectra,
  - c) emission spectra, and
  - d) absorption spectra.

If available, show examples of them to students, being careful not to reveal the sources of the spectra at this time.
5. Set the scenario for the activity by telling the students that they have been captured by a diabolical spectroscopist who has placed them in a dimly lit cave. He has told them that they must demonstrate a good knowledge of electromagnetic radiation before the light will be allowed to shine in the cave once again. They should do their best and follow the directions of the diabolical spectroscopist, as expressed through his able assistant, as they proceed through the various parts of the activity. You, playing the role in the activity of the friendly able assistant, will work along with the students and supply them with the materials needed to complete the various parts of the activity.
6. For Part 2, have the students use a spectroscopy to view the light coming from several incandescent sources if at all possible. The more spectra that the students observe, the easier it will be for them to formulate something resembling Kirchhoff's first law.
7. For PART 4 of the Student Activity emphasize that students should observe the sun's rays as they are reflected off of a shiny object such as the bottom of a flat stainless steel frying pan. Other shiny objects, such as automobile bumpers, will work as well.
8. You may want to have beginning students stop after completing Part 4. If so, continue class discussion using the Follow-up Questions.
9. For PARTS 5 and 6 of the Student Activity, you should make available as many samples for the student to observe as is practical.
10. Part 7. What you do in this part of the activity again will be determined by the instruments that you have available. Students will be using Fraunhofer lines in the solar spectrum to identify an element other than H or He in the sun. Observing these lines with an inexpensive spectroscopy is difficult. Obtaining sufficiently quantitative data for element identification is even more difficult. However, if you have access to a good spectroscopy, it may be possible to have the students actually make the necessary measurements themselves. This clearly is a determination that you will have to make. It would be pedagogically sound to provide them with an opportunity to at least confirm the existence of the lines. This can be done qualitatively with a simple diffraction grating and following the directions given on the Web site:  
<http://thor.nmsu.edu/education/lab110g/html/AFRANHFER.html>

#### Teaching Tips

Generally the accuracy of the measuring scales of instruments is a function of their cost, and what one pays often reflects the effort made to insure the accuracy of the instrument rather than the cost of materials and assembly. The students need to understand that the accuracy of a school-grade spectroscopy is not high. Hence the need to calibrate the instrument if they are to use it for even semi-quantitative purposes. Calibration can be accomplished by making a measurement and comparing the result to a known value. An instrument "calibration factor" can then be determined as the value that must be added to or subtracted from the instrument reading to make it agree with the known value.

#### Teaching Tips

Students should:

- a) Aim the spectroscopy slit away from the brightest portion of the light bulb; and
- b) NOT POINT the spectroscopy DIRECTLY at the sun.

#### Teaching Tips

Although the primary interest in this activity is in the spectra of atomic materials and simple ions, molecules often emit light in the visible part of the spectrum as well. The phenomenon is the same. Electrons that have been excited to higher energy states by an external stimulus, such as chemical energy or electrical energy, fall back to lower states with the emission of photons.

Another option is to obtain a copy of the solar spectrum from the following Web site:  
<http://www.eckerd.edu/academics/nas/chn/CHN209S/solar.html>



In any case, give the students a copy of the Table of Strong Fraunhofer lines. Ideally you should have available a quantitative Solar Spectrum Chart from which the students can identify one or more elements.

If you are unable to demonstrate/measure the Fraunhofer lines, provide the students with a copy of the simulated solar spectrum having some Fraunhofer lines marked on it and let them analyze it to identify two elements that are found in the sun in addition to H and He.

## FOLLOW-UP QUESTIONS

1. What part of the eye might be seriously damaged by looking directly at the sun?
2. Are there other units in which the wavelengths of spectral lines could be measured, in addition to nanometers and Ångströms?
3. After examining a copy of Kirchoff's Laws—either in a handout, on the board, or on the overhead—list other things in everyday life that might
  - a) give a continuum spectrum; and,
  - b) provide line spectra.
4. Why might it be experimentally difficult to demonstrate Kirchoff's third law in their classroom?
5. What is implied by the fact that detailed studies of the solar spectrum show the presence of many Fraunhofer lines?
6. What is the significance of the fact that some Fraunhofer lines are strong (dark lines), and others are weak? Discuss as a class what this might mean.
7. Explain why it is incorrect to say, "Atoms emit absorption lines."
8. Heat a piece of glass rod or tubing in a flame. Guess the wavelength of the very bright yellow emission that is seen. *Either use this demonstration to lead into the fact that sodium salts are used in the manufacture of glass, or have students research the manufacture of glass and come to their own conclusion that it contains a lot of sodium. Follow up with these questions:*
  - a) Why are sodium ions a major contaminant of most surfaces, especially those that have been touched by humans?
  - b) After studying the Table of Strong Fraunhofer Lines decide why glassblower's protective glasses contain neodymium.
9. Predict what you would observe if the light from a gallium arsenide laser or an LED, which have wavelengths of 670 nm in both cases, is passed through a solution of Vanish®. How would this differ from what would happen when light from a helium-neon laser, which produces a bright red line at 633 nm, is passed through a solution of Vanish®?
10. If we can detect elements in the sun spectroscopically, why is it necessary to send a Genesis mission spacecraft up for two years to collect elements streaming from the sun? *Hopefully, students will realize after some reflection that nothing has been said in this activity about detecting and identifying isotopes through the study of emission or absorption spectroscopy.*

### Rydberg

For hydrogen, and hydrogen alone, it is possible to calculate the positions of the lines in the emission spectrum with a high degree of accuracy. To do so involves solving the Rydberg equation:

$$1/\lambda = R(1/n_1^2 - 1/n_2^2)$$

The values that  $n_1$  and  $n_2$  can take are 1, 2, 3, 4, 5, . . .  $\infty$ . These values designate the various orbitals of the hydrogen atom, the orbital size and energy increasing with  $n$ . A transition from an excited state to a state of lower energy results in the emission of a photon having energy that matches the energy difference between the two states. Lambda ( $\lambda$ ) is the wavelength of the emission line in cm and R is the Rydberg constant, which has the value  $109,677.58 \text{ cm}^{-1}$ . In applying the Rydberg expression it is necessary that  $n_2$  be greater than  $n_1$ . Transitions from excited states (i.e. any state having  $n$  greater than one) to the state where  $n$  equals one give rise to the Lyman series of lines, which are found in the ultraviolet. The Balmer, Paschen, Brackett, and Pfund series of lines correspond to transitions back to the 2nd, 3rd, 4th, and 5th orbitals, respectively. The Balmer lines are found in the visible region, whereas all of the others are in the infrared. More advanced students are encouraged to calculate the wavelengths of several of the Balmer lines and compare their results with the experimentally determined wavelengths. They will find remarkably agreement between the values.

Students who are interested in computers and programming might wish to simulate the emission spectrum of atomic hydrogen by writing computer code that allows them to calculate the lines in one or more of these series. The excellent graph-plotting functions available for most modern machines helps bring this exercise to life.

## TEACHER RESOURCES

### Fraunhofer Lines:

[http://imagine.gsfc.nasa.gov/docs/science/known/cool\\_sun\\_fact.html](http://imagine.gsfc.nasa.gov/docs/science/known/cool_sun_fact.html)

An informative site on Fraunhofer lines.

<http://thor.nmsu.edu/education/lab110g/html/AFRANHFER.html>

A site that offers information on observing Fraunhofer lines.

### Spectroscopes:

Thompson, K. (1996) An Easy-to-Build Spectroscope. Physics Education, 31, p. 382.

Edmund Scientific Company  
101 E. Gloucester Pike, Barrington, NJ 08007-1380  
Phone: 1-800-728-6999